Photo-oxidative damage in Cucumis leaves during chilling

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SUMMARY

Low temperatures below the freezing point cause freezing injury to plants. The direct cause of freezing injury is the formation of ice in the plant tissue. Many thermophilic ("heat loving") plants, however, are already damaged at low temperatures above the freezing point. This is called chilling injury.

One of the research projects of our department deals with the causes of chilling injury to plants. It was observed that chilling in the light caused more damage than chilling in darkness. Evidentily light had a damaging effect during chilling. It was the purpose of this study to obtain more insight in the nature of the light-induced damage during chilling and in its underlying mechanism.

The experiments were carried out on circular discs from the leaves of the thermophilic plant *Cucumis sativus*. These were exposed to light at an intensity of 20,000 lux, at 1°C.

In chapter II the light-induced degradation of leaf pigments in Cucumis leaf discs at 1°C is described. The degradation is caused by a photo-oxidative process. A lag phase precedes a fast phase of degradation. The sensitivity of the pigments to photo-oxidation corresponds with the lenght of the lag phase. Carotene is most sensitive followed by xanthophyll, chlorophyll a and chlorophyll b respectively. The lag phase disappears after boiling of the discs for 10 minutes.

Chapter III reports the effect of light on the triphenyltetrazoliumchloride (TTC) reducing capacity. After a short lag phase this capacity rapidly decreases. The decrease is inhibited by DCMU. A crude action spectrum of the effect on TTC reduction indicates that light absorption by both, chlorophyll and carotenoids, induces the harmful effect.

The photo-oxidative degradation of unsaturated lipids from Cucumis leaves at 1°C is described in chapter IV. Again a lag phase precedes a fast phase of degradation. DCMU inhibits unsaturated fatty acid photo-oxidation. Linolenic acid is the most abundant fatty acid in the Cucumis leaf (72,6%) and is most sensitive to photo-oxidation. A crude action spectrum indicates that degradation of unsaturated fatty acid is induced by light which is absorbed by both, chlorophyll and carotenoïds.

Chapter V deals with the electronmicroscopic study of the photo-oxidative damage of Cucumis chloroplasts during chilling. First the chloroplast envelope disappears and the inner membranes swell. The next stage of damage is a loss of the inner chloroplast structure due to formation of vesicles by grana and stroma tylakoids.

The effect of different wavelenghts of visible light on the photo-oxidative degradation of Cucumis leaf pigments both in 80% acetone and in leaf discs is described in chapter VI. The action spectra of chlorophyll a, chlorophyll b and carotene degradation in leaf discs are similar and resemble the absorption spectrum of a Cucumis leaf. The blue-violet and blue wavelenghts are most effective because the lag phase is shorter in this part of the spectrum than in the red spectral region. The maximal effect in the red region is at 667 nm.

A model of the mechanism of photo-oxidative damage in Cucumis leaves at 1°C is proposed in chapter VI. It states that the damage is primarily caused by singlet oxygen originating from the quenching of excited triplet chlorophyll by atmospheric oxygen.
The effect of some chemicals on photo-oxidative pigment degradation is described in chapter VII. DCMU has an inhibitive effect. Substances which probably quench chlorophyll directly, as benzoquinone and benzidine also inhibit photo-oxidation. Photo-oxidation of leaf pigments is accelerated by benzylviologen and inhibitors of electron flow between water and photosystem II as azide and salicylaldoxime. It is concluded that photosystem II is closely associated with the mechanism which prevents photo-oxidation.